

## Topic 5: Alkenes

Related topics in Units 2, 4 and 5 will assume knowledge of this material.

**Students will be assessed on their ability to:**

<b>5.1</b>	<p>know the general formula of alkenes and understand that alkenes and cycloalkenes are hydrocarbons which are unsaturated (have a carbon-carbon double bond which consists of a <math>\sigma</math> bond and a <math>\pi</math> bond)</p> <p>All <b>alkenes</b> contain a C=C double bond so they are all unsaturated compounds</p> <p>General Formula: <math>C_nH_{2n}</math></p> <p>The fact that they contain a C=C bond means they are more reactive than <b>alkanes</b></p> <p>Cycloalkenes have the general formula <math>C_nH_{2n-2}</math></p> <p>When forming a covalent bond, the orbitals overlap in such a way to form two types of bonds: sigma and pi bonds</p> <p><math>\pi</math> bonds (a.k.a C=C double bonds) are exposed and have high electron density hence they are more vulnerable to attack by electrophiles (electron-loving species)</p>
	<p><u>Formation of a (<math>\sigma</math>) sigma bond</u></p> <ul style="list-style-type: none"> <li>- Sigma bonds are formed from the end to end overlap of atomic orbitals (this is true for both s and p orbitals)</li> <li>- Rotation can occur around a sigma bond</li> </ul> <p><u>Formation of a (<math>\pi</math>) pi bond</u></p> <ul style="list-style-type: none"> <li>- <i>Pi bonds are formed from the sideways overlap of adjacent p orbitals</i></li> <li>- A single pi bond has two-electron clouds, one above and one under the plane of the sigma bond (each electron cloud representing one bond containing two electrons)</li> <li>- This arrangement maximises the overlap of the p-orbitals</li> </ul>
<b>5.2</b>	<p>be able to explain geometric isomerism in terms of restricted rotation around a C=C double bond and the nature of the substituents on the carbon atoms</p> <p>In saturated compounds, the atoms/functional groups attached to the single, <math>\sigma</math>-bonded carbons are not fixed in their position due to the free rotation about the C-C <math>\sigma</math>-bond</p> <p>In unsaturated compounds, the groups attached to the C=C carbons can only be in one of two positions, and they remain fixed in that position</p>

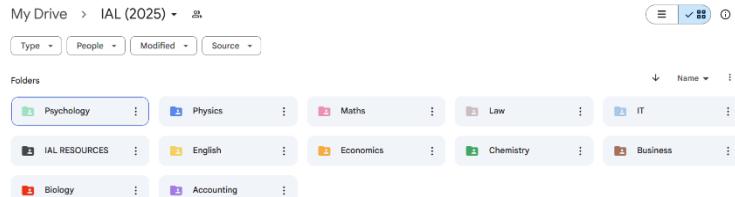
	<p>For compound A and B to be geometric isomers, There must be two different atoms or group of atoms on each carbon of the double bond and there is restricted rotation about the double (C=C) bond This means each geometric isomer has different physical and chemical properties</p>
<b>5.3</b>	understand the <i>E-Z</i> naming system for geometric isomers and why it is necessary to use this when the <i>cis-</i> and <i>trans-</i> naming system breaks down
E = Trans Z = Cis	<p><i>Cis-</i> and <i>trans-</i> naming system can only be used when we have only one functional group (or atom) on each side of the C=C double bond</p> <ul style="list-style-type: none"> <li>- If we have more than one, the <i>E-Z</i> naming system has to be used:</li> <li>- Priority is decided by which atom has the higher atomic number</li> <li>- If both atoms are above or below the double bond, then it is a Z-isomer</li> <li>- If one is above and one below, then it is an E-isomer</li> </ul>
<b>5.4</b>	<p>be able to describe the reactions of alkenes, limited to:</p> <ol style="list-style-type: none"> <li>i the addition of hydrogen, using a nickel catalyst, to form an alkane</li> <li>ii the addition of steam, in the presence of an acid catalyst, to produce alcohols</li> <li>iii the addition of hydrogen halides to produce mono-substituted halogenoalkanes</li> <li>iv the addition of halogens to produce a di-substituted halogenoalkane</li> <li>v oxidation of the double bond by acidified potassium manganate(VII) to produce a diol</li> </ol>
<b>i</b>	<p>An electrophilic addition reaction is the addition of an electrophile to a double bond (this includes all the reactions from i to iv)</p> <p>As stated above, the <math>\pi</math> bonds in alkenes are areas with high electron density and the fact that a <math>\pi</math> bond is weaker than a <math>\sigma</math> bond so less energy is needed to break <math>\pi</math> bond means it is more vulnerable (susceptible/ accessible) to electrophilic attack by electrophiles</p> <p style="text-align: center;"><b>Alkene</b>      <b>Change in functional group</b>      <b>Alkane</b></p>
<b>ii</b>	<p style="text-align: center;"><b>Alkene</b>      <b>Change in functional group</b>      <b>Alcohol</b></p>
<b>iii</b>	<p style="text-align: center;">Heterolytic Fission in bond</p> <p style="text-align: center;"><b>Alkene</b>      <b>Change in functional group</b>      <b>Halogenoalkane</b></p>

	<p>Dissolved in organic solvent</p> <p>Heterolytic Fission in bond</p>
iv	<p>Alkene      Change in functional group → dihalogenoalkane</p>
v	<p>On top of electrophilic addition reaction, <b>alkenes</b> can also be oxidised by shaking it with cold dilute KMnO4 (acidified potassium manganate(VII)) Pale purple solution turns colorless (a <b>diol</b> is produced) This can also be used as a test for alkenes just like bromine water</p> <p>Alkene      Change in functional group → diol</p>
5.5	<p>know the qualitative test for a C=C double bond using bromine or bromine water</p> <p><u>Bromine Water Test</u> Shake the unknown compound to be tested with bromine water in a test tube If it is unsaturated (has double bonds), addition reaction will occur and the solution will turn from orange to colorless (A qualitative test shows a yes or no, if its present or not, it doesn't how much it contains)</p> <p>It's better to know the colors of bromine in different states (orange in solution, red-brown liquid at room temperature and orange vapour)</p>
5.6	<p>be able to describe the mechanism (including diagrams), giving evidence where possible, of:</p> <ol style="list-style-type: none"> <li>the electrophilic addition of bromine and hydrogen bromide to ethene</li> <li>the electrophilic addition of hydrogen bromide to propene</li> </ol> <p><i>Use of the curly arrow notation is expected – the curly arrows should start from either a bond or from a lone pair of electrons.</i></p> <p><i>Knowledge of the relative stability of primary, secondary and tertiary carbocation intermediates is expected.</i></p>
i	<p>PRIMARY carbocation</p> <p>- Although Br<sub>2</sub> in itself is non-polar, it can have an induced dipole when it is moved closer to a high electron density C=C bond of the alkene</p>

ii	<p style="text-align: center;">PROPENE</p> <p style="text-align: center;">secondary carbocation</p> <p style="text-align: center;">MAJOR product</p> <p style="text-align: center;">primary carbocation</p> <p style="text-align: center;">MINOR product</p>
	<ul style="list-style-type: none"> <li>- HBr is a polar molecule as Br is more electronegative than H, the H atom acts an electrophile and is attracted to the electron-rich pi bond of propene and accepts a pair of electrons</li> <li>- The <math>\text{Br}^-</math> ion acts as a nucleophile</li> <li>- Secondary carbocations are more stable as there are more electron-releasing alkyl groups attached to the carbon with the positive charge</li> <li>- The major product is formed via the more stable carbocation intermediate</li> <li>- Order of stability for carbocations: Tertiary &gt; Secondary &gt; Primary</li> </ul>
<b>5.7</b>	be able to describe the addition polymerisation of alkenes and draw the repeat unit given the monomer, and vice versa
	<b>Addition polymerization</b> is the reaction in which many monomers containing at least one C=C double bond form long chains of polymers as the only product
<b>5.8</b>	understand how chemists limit the problems caused by polymer disposal by: <ul style="list-style-type: none"> <li>i developing biodegradable polymers</li> <li>ii removing toxic waste gases produced by the incineration of polymers</li> </ul>
<b>i</b>	Biodegradable means it can be broken down by micro-organisms over time The polyester and polyamide condensation polymers are considered to be biodegradable as they can be broken down using hydrolysis reactions whereas poly(alkenes) cannot
<b>ii</b>	The toxic waste gases produced incineration such as HCl can be reacted with a base or carbonate, the base reacts with the acidic HCl thereby neutralizing it
	<b>Further suggested practicals:</b> <ul style="list-style-type: none"> <li>i investigating the difference in reactivity of alkanes and alkenes, including combustion, reaction with bromine water, reaction with acidified potassium manganate(VII)</li> <li>ii preparation of cyclohexene from cyclohexanol</li> <li>iii preparation of limonene from orange peel by steam distillation</li> <li>iv preparation of Perspex® from methyl 2-methylpropenoate</li> </ul>

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